Chapter 3
The Khorassan-Kopet Dagh Mountains

Farshid Memariani

Abstract The Khorassan-Kopet Dagh Mountains are mainly east-west oriented ranges in the northeastern Iran. The climate of the area is continental and distinctly drier than the nearby mountain ranges. A total of 2576 species or infraspecific taxa belonging to 702 genera and 112 families are recorded from these mountains. It is known as a separate floristic province and is a transitional zone between the different phytogeographical units of the Irano-Turanian region. Near to 65% of the species are Irano-Turanian elements, and the level of endemism is about 14%. In spite of the uniform and dry climate of the Khorassan-Kopet Dagh, the heterogeneous topography supported the diverse vegetation types in the region. The major vegetation types of these mountains are Hyrcanian montane forests, Juniper woodlands, *Pistacia* woodlands, mesophilic shrublands, montane steppe shrublands, subalpine thorn-cushion communities, *Stipa-Artemisia* steppes, chasmophytic vegetation, edaphic vegetation, halophytic vegetation, psammophyte vegetation, wetlands, and ruderal vegetation. In recent decades, extensive urbanization and industrialization caused dramatic degradation in the natural ecosystems and the biodiversity of the Khorassan-Kopet Dagh. Almost all populations of endemic taxa outside the protected areas are severely threatened and need to be protected.

Abbreviations

ES Euro-Siberian
IT Irano-Turanian
M Mediterranean
SS Saharo-Sindian
KK Khorassan-Kopet Dagh

F. Memariani (✉)
Herbarium FUMH, Department of Botany, Research Center for Plant Sciences, Ferdowsi University of Mashhad, Mashhad, Iran
e-mail: memariani@um.ac.ir

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3.1 Introduction

The mountainous area of the Khorassan-Kopet Dagh (KK) is located mainly in northeastern Iran and partly extending into the neighboring parts of southern Turkmenistan. The KK area lies between 34°20′ and 39°13′ N latitude and 55°05′ and 61°20′ E longitude, and has a surface area of *ca.* 165,000 km^2. It is delimited sharply in the north and northwest by the Kara-Kum desert; in the east by the Iran-Turkmenistan border along the Tajan River and western Badghyz and partly by the Iran-Afghanistan border along the Harir-Rud River and the western extension of the Paropamisus Range; and in the south and southwest by the central Iranian deserts. To the west, the area is connected partly to the Gorgan plain and Turkman-Sahra salt desert, and partly to the eastern extension of the Alborz mountain range and the Hyrcanian forests of the ES region. There are several east-west oriented mountain ranges in the area (Fig. 3.1). The Kopet Dagh range is located in the northernmost part of the area and stretches from the northwest in Turkmenistan to the southeast in Iran, traversed by the Tajan River forming the Iran-Turkmenistan border. Chapandag (2889 m a.s.l.) and Shakh-Shakh Mountain (2912 m a.s.l.) are the highest peaks of the central Kopet Dagh in Turkmenistan (Kamakhina 1994; Rustamov 2012). The Iranian part of the Kopet Dagh range, its central and eastern areas, includes the high peaks Hezar-Masjed (3106 m a.s.l.) and Allaho-Akbar (2676 m a.s.l.). The northern ranges of Khorassan run parallel to the Kopet Dagh and are constituted mainly by the mountains Binalood (3301 m a.s.l., the highest peak in the KK), Shah-Jahan (3062 m a.s.l.), Salook (2956 m a.s.l.), Ghorkhod (2771 m a.s.l.) and Aladagh (2763 m a.s.l.). The Sabzevar and Kashmar-Torbat ranges are oriented mainly east-west at the southern border of the KK, where Bezq (2940 m a.s.l.) and Kuh-e Gar (2937 m a.s.l.) are the highest peaks. There are several low and high plains as well as foothills in the area between these main mountain ranges (Memariani et al. 2016a). The isolated Bolshoi Balkhan range (up to 1883 m a.s.l.) forms the northwestern periphery of the Kopet Dagh and is surrounded by the sand deserts east of the Caspian Sea (Kurbanov 1994). The vegetation of the Bolshoi Balkhan is quite peculiar in its structure, composition and outlook, and does not repeat that of the Kopet Dagh (Proskuriakova 1971).

The KK is considered as a separate floristic province within the IT region. The area is actually a transitional zone and a corridor connecting different phytogeographical units of the IT region, i.e. the central Iranian deserts, the Aralo-Caspian (Turanian) deserts, the Central Asian, Afghanistan, and Alborz Mountains, and also the Hyrcanian province of the ES region. The area might have been isolated in earlier geological times, resulting in allopatric speciation of many related species of the surrounding area. The separate biogeographic identity of the KK has been emphasized by several plant geographers (Fet 1994b; Takhtajan 1986; Kamelin 1970; Kamelin 1973; Meusel et al. 1964, 1978, 1992).

There are extensive floristic data on Khorassan published in connection with the Flora Iranica (Rechinger 1963–2015), Flora of Iran (Assadi et al. 1988–2018), and several local floristic studies (e.g. Akhani 1998, 2005; Ghahreman et al. 2006;

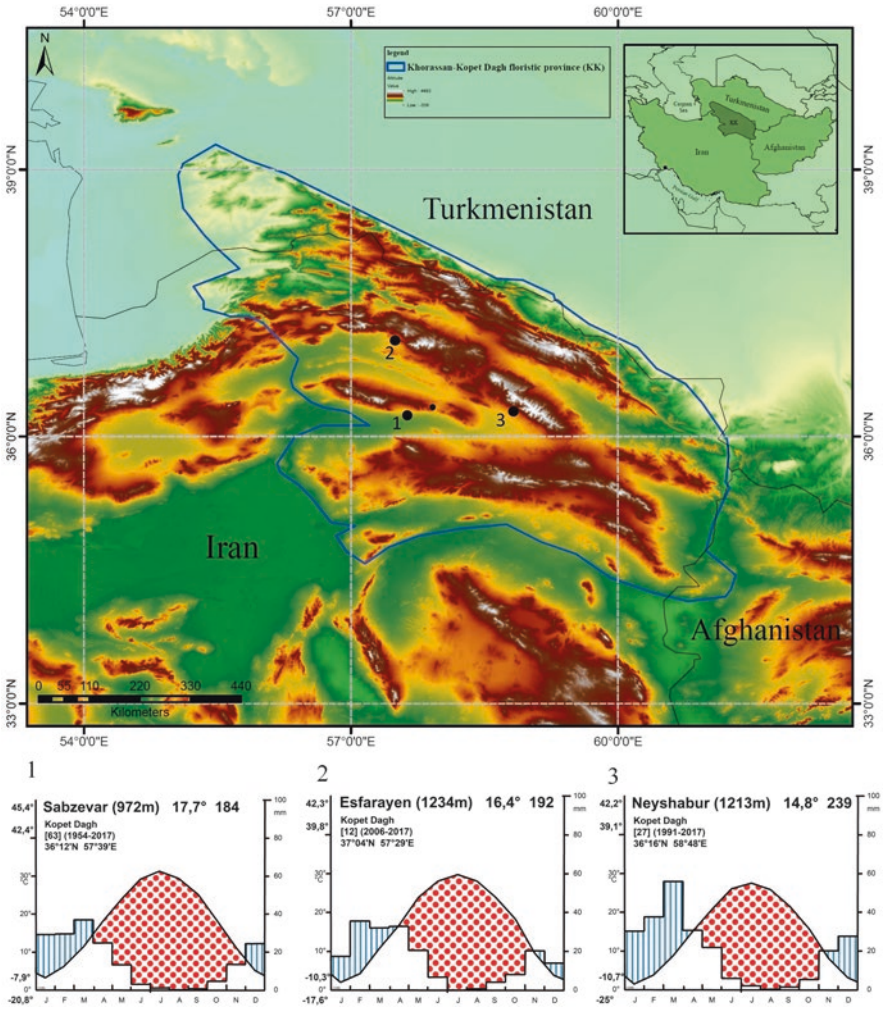

Fig. 3.1 Geographical delimitation and topography of the KK floristic province in northeastern Iran and partly in southern Turkmenistan and the climatic diagrams from different regions

Gholami et al. 2006; Memariani et al. 2009, 2016c; Saberi et al. 2010; Amiri and Jabbarzadeh 2011; Atashgahi et al. 2018). Since the publication of the Flora Iranica, many new species have been recorded for the flora of Khorassan or newly described from the area and listed in a series of papers as supplements to the Flora Iranica (Ghahremaninejad et al. 2005, 2010, 2012; Joharchi et al. 2007, 2011). The Turkmen part of the KK province was floristically explored in the course of the preparation of the *Manual of Plants of Turkmenistan* (Nikitin and Geldikhanov 1988). Memariani et al. (2016a) provided a comprehensive and up-to-date evaluation of the plant biodiversity, distribution patterns, and biogeography of the whole area of the KK

floristic province. Memariani et al. (2016b) determined a level of about 14% endemism and showed the Red-Listing and clear distribution patterns of the endemic species in the area. However, the province is strongly influenced by the flora of the surrounding mountains and deserts, in particular by Central IT elements (Memariani et al. 2016a). Actually, the KK is part of the Irano-Anatolian mountain system, which is recognized as one of the 35 so-called hotspots of biodiversity in the World (Mittermeier et al. 2011).

3.2 Geology

A detailed geological description of the KK was carried out by the National Iranian Oil Company (NIOC) during the 1960s and 1970s (Kalantari 1969; Afshar-Harb 1969, 1979; Hubber 1976). The Northern Khorassan and Kopet Dagh sedimentary basin formed after the closure of the Paleotethys Ocean and the convergence of the Iranian and Turanian plates following the Middle Triassic orogeny. Relatively continuous sediment deposition took place in this basin from the Jurassic through the Neogene (Berberian and King 1981; Afshar-Harb 1994). The Jurassic sediments in the basin are divided into Bashkalateh, Chaman-Bid and Mozduran formations composed mainly of sandstones, limestones, marls, and dolomites. The Cretaceous sediments include nine formations, i.e. the Shurijeh, Tirgan, Sarcheshmeh, Sanganeh, Aitamir, Abderaz, Abtalkh, Neyzar and Kalat, composed of sandstone, conglomerates, marl, mudstone, and dolomite. The sedimentary structure of the Paleogene is composed of different formations, including the Pesteligh, Chehel-Kaman, and Khangiran (Hubber 1976; Haghipour and Aghanabati 1989). The thickness of these sediments is normally 4 km and reaches up to 9 km in the Iranian portion but only about 2.5 km in the eastern parts, indicating that the Sarakhs area was more stable than the other areas of the basin (Afshar-Harb 1979). The Kopet Dagh basin was folded during the Paleogene and created many anticlinal traps, such as those that contain the Khangiran and Gonbadli gas fields in NE Iran (Mahboubi et al. 2006).

Sedimentary rocks constitute much of the continental crust of KK, especially in the Kopet Dagh range. Binalood is composed mainly of metamorphic rocks in its central and eastern parts and partly of sedimentary rocks in the western parts. Igneous and ophiolitic rocks occur widely in the Sabzevar and Kashmar-Torbat ranges. The main plains of the KK are composed of Quaternary deposits. The entire area is characterized by high seismic activity.

3.3 Climate

Due to distance from the oceans, the climate of the area is distinctly continental and drier than the nearby mountainous areas (Fig. 3.2). Based on available data, the mean annual precipitation usually is 175–300 mm in the plains and foothills and 300–380 mm in the high mountains. However, less precipitation falls in the transitional zones between the Karakum desert in the north and the central Iranian deserts in the south, and higher precipitation is expected in isolated areas of montane oak forest (*Quercus castaneifolia*) in the humid valleys of the western Aladagh range in North Khorassan. The precipitation has an uneven annual distribution throughout the area and falls predominantly in late autumn, winter and early spring, from October to May (Memariani et al. 2016a). A prolonged summer drought (from June to September) is common (Fig. 3.1). The highest mean monthly air temperatures occur from June to August. The maximum temperature in the warmest month rarely exceeds 45 °C. The lowest mean monthly temperatures are from December to February, with cold-month average minima below freezing point and down to −25 °C in high mountains (Djamali et al. 2011).

Using the Bioclimatic Classification System (Djamali et al. 2011) and its improved version (Djamali et al. 2012), most of the KK mountain area is covered by a Mediterranean or Irano-Turanian xeric-continental bioclimate, except for the high mountain areas in the central KK, where a Mediterranean or Irano-Turanian pluvi-seasonal-continental bioclimate can be found with shorter summer droughts and higher annual precipitation values (Fig. 3.1). An Irano-Turanian desert-continental climate covers mainly the eastern KK lowlands and part of the Daregaz low plains in the northern part of the area, with a much longer dry season that lasts at least 8 months (Fig. 3.1).

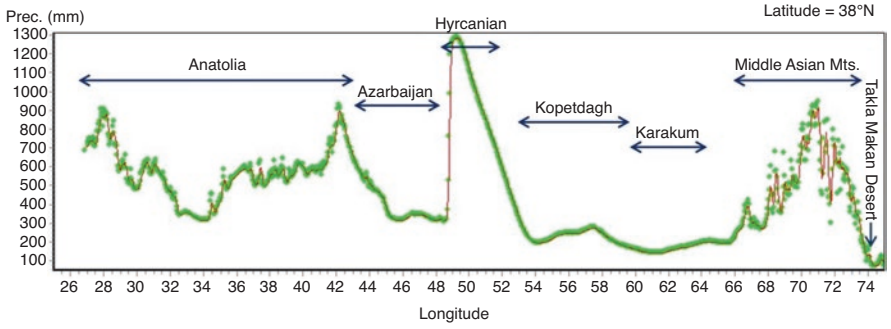

Fig. 3.2 A transect of mean annual precipitation (mm) from the Western IT (Anatolia) to the Eastern IT (the Middle Asian Mountains) region along 38° N latitude, showing the position of the Kopet Dagh Mountains. (After Memariani et al. 2016a)

3.4 Flora and Phytogeography

3.4.1 Plant Diversity

The vascular flora of the KK floristic province includes a total of 2576 species or infraspecific taxa belonging to 702 genera and 112 families. The Dicots as the most diverse plant group are composed of 84 families, 562 genera and 2145 species which comprise 83.2% of the total flora. The Monocots, with 21 families, 130 genera and 409 species, comprise 15.9%. The least diverse groups are the Gymnosperms, with 3 families, 4 genera and 12 species; and Pteridophytes, with 4 families, 6 genera and 11 species. The floristic composition of the area shows the dominance of Angiosperms and a 5:1 ratio of Dicots to Monocots which is typical of Iranian and Middle Asian floras. Totally, 52 Bryophyte species have been recorded from Khorassan province, mainly from wet places in the western KK, comprising 11.9% of the Iranian Bryoflora (Akhani and Kürschner 2004).

The largest families are the Asteraceae (426 species or infraspecific taxa), Fabaceae (290), Poaceae (196), Brassicaceae (177), Apiaceae (136), Caryophyllaceae (125), Chenopodiaceae (107), and Lamiaceae (102). Thirteen families, each with more than 40 species, comprise 71.5% of the flora. The richest families in the number of genera are Asteraceae, Poaceae, Apiaceae, and Brassicaceae, with 99, 77, 69 and 64 genera, respectively (Table 3.1).

The largest genera in the flora of the KK are *Astragalus* (Fabaceae; 158 species) and *Cousinia* (Asteraceae; 108), *Allium* (Amaryllidaceae; 42), *Euphorbia* (Euphorbiaceae; 31), *Silene* (Caryophyllaceae; 31), *Alyssum* (Brassicaceae; 28), *Acantholimon* (Plumbaginaceae; 26), *Acanthophyllum* (Caryophyllaceae; 26), *Trigonella* (Fabaceae; 23), *Vicia* (Fabaceae; 22) and *Veronica* (Plantaginaceae; 21)

Table 3.1 The largest families of vascular plants in the flora of the KK

Family	Species	Genera
Asteraceae	426	99
Fabaceae	290	27
Poaceae	196	77
Brassicaceae	177	64
Apiaceae	136	69
Caryophyllaceae	125	23
Chenopodiaceae	107	37
Lamiaceae	102	30
Boraginaceae	80	23
Rosaceae	71	16
Amaryllidaceae	46	3
Polygonaceae	44	7
Ranunculaceae	42	12
99 other families	734	215
Total	2576	702

are among the other polymorphic genera (Table 3.2). In all, 1110 species belonging to 592 monotypic and oligotypic genera (with ≤5 species) comprise 43% of the flora. *Nikitinia* (Asteraceae) was considered as the only endemic genus within the area before it has been reduced as a section within *Klasea* (Martins and Hellwig 2005). *Diaphanoptera* (Caryophyllaceae) and *Sclerorrhachis* (Asteraceae) are two subendemic genera in the flora of the KK.

3.4.2 Phytogeography

As a separate floristic province within the IT region, the KK is located at the crossroad between different areas and provinces of the IT region and the Hyrcanian province of the ES region. The geographic position of the area has led to a unique mixture of elements from the surrounding areas and the presence of many widespread, wide-ranging elements. Simultaneously, the core IT species and many local and narrowly distributed endemic species have produced a biogeographically distinctive area. Memariani et al. (2016a) distinguished 28 distribution patterns for the KK flora classified in five main categories, namely Widespread, Tri-regional, Bi-regional, ES and IT elements (Table 3.3).

The relatively wide extent of the area and the diversity of different habitats have made suitable conditions for many ruderal plants and weeds as well as hygrophilous and aquatic plants. About 295 widespread species comprise 11.4% of the KK flora, including Pluri-regional (PL), cultivated, sub-cosmopolitan (SCO), and cosmopolitan (COS) elements.

The wide-range Tri-regional species make up to 7.5% of the KK flora. They occur concurrently in the IT and two other adjacent regions of the ES, M, and/or the SS regions. Three patterns can be distinguished in this category including IT-ES-M, IT-M-SS, and IT-ES-SS. The IT-ES-M is the main pattern of the Tri-regional elements with 173 species (6.8%). Bi-regional species (14.3%) show four different

Table 3.2 The largest genera of vascular plants in the flora of KK

Genera	Species no.	Endemism (%)	Genera	Species No.	Endemism (%)
Astragalus	158	44	*Gagea*	20	10
Cousinia	107	59	*Scorzonera*	20	0
Allium	42	36	*Scrophularia*	20	25
Euphorbia	31	13	*Taraxacum*	20	5
Silene	31	16	*Bromus*	19	5
Alyssum	28	0	*Artemisia*	18	11
Acantholimon	26	54	*Polygonum*	17	0
Acanthophyllum	26	23	*Centaurea*	16	12
Trigonella	23	22	*Onobrychis*	15	20
Vicia	22	5	*Echinops*	15	0
Veronica	21	14	*Valerianella*	15	0

Table 3.3 Numbers and proportions of plant species in different phytogeographical groups in the flora of the KK (Memariani et al. 2016a). (For abbreviations, please refer to the text)

Phytogeographical groups		Taxa no.	Taxa (%)
Widespread	PL	215	8.3
	SCO	41	1.6
	Cultivated	20	0.8
	COS	19	0.7
	(Total)	***(295)***	***(11.4)***
Tri-regional	IT- ES- M	173	6.7
	IT- M- SS	19	0.7
	IT- ES- SS	2	0.1
	(Total)	***(194)***	***(7.5)***
Bi-regional	IT- M	175	6.8
	IT- ES	136	5.3
	IT- SS	38	1.5
	ES- M	18	0.7
	(Total)	***(367)***	***(14.3)***
Euro-Siberian (ES)	ES ^{EH}	28	1.1
	ES ^{HY}	15	0.6
	ES	8	0.3
	(Total)	***(51)***	***(2.0)***
Irano-Turanian (IT)	IT ^{KK}	356	13.8
	IT ^{C}	331	12.8
	IT or IT^{omni}	261	10.1
	IT $^{C\ \&\ E}$	220	8.5
	IT $^{W\ \&\ C}$	110	4.4
	IT $^{KK\text{-}E}$	96	3.7
	IT $^{KK\text{-}Alborz}$	87	3.4
	IT $^{KK\text{-}Afgh.}$	83	3.2
	IT $^{Aralo\text{-}Caspian}$	37	1.4
	IT $^{Cauc.\text{-}Turk.}$	30	1.2
	IT ^{E}	25	1.0
	IT $^{Cauc.\text{-}Alborz}$	15	0.6
	IT ^{Alborz}	15	0.6
	IT ^{W}	3	0.1
	(Total)	***(1669)***	***(64.8)***
	Whole KK flora	**2576**	**100.0**

distribution patterns among which the IT-M and IT-ES are the main ones with 175 (6.8%) and 136 (5.3%) species, respectively.

In the western and southwestern parts of the KK, mainly in wet valleys of the Ghorkhod Protected Area (just east of the Golestan National Park) and the western Aladagh mountains (Darkesh and Jowzak forests), some isolated Hyrcanian relict forests have loosely affected the phytogeographical spectrum of the area by their ES elements of up to 2%. Actually, some Euxino-Hyrcanian, Hyrcanian, and a few

omni- ES species occur in wet valleys of the KK at the easternmost extremes of their distribution range (Memariani et al. 2016c).

The IT elements (1669 species, 64.8%) constitute a considerable proportion of the flora of the KK. Based on the delimitation of the IT chorotypes proposed by Akhani (1998) and Memariani et al. (2016a), several distribution patterns can be distinguished in this group. A significant number of the IT species, i.e. 356 species (14%), are local or narrowly endemic species that do not occur outside the defined boundaries of the KK. The endemic KK pattern (IT^{KK}) is followed by the Central (IT^{C}) and overall IT/IT^{Omni} groups with 331 (13%) and 261 (10%) species, respectively. The foothills and mountains of the KK represent the northern limits of many Central IT elements. The eastern and/or western range of those species occurring either widely in the whole IT region, the Central-Eastern IT (220 species) and/or Western-Central IT (110 species) are connected in the KK mountains. These five chorotypes (i.e. IT^{KK}, IT^{C}, IT/IT^{Omni}, $IT^{C\&E}$, and $IT^{W\&C}$) constitute about 50% of the KK flora which reflect the relative importance of local endemism and the central areas of IT region in the phytogeography of the KK.

Moreover, the KK flora shows a remarkable phytogeographical link to the adjacent Middle Asian, Alborz, Afghan, and Caucasian mountain ranges. Several Eastern IT species (mainly the Middle/Central Asian) have a disjunct distribution in KK or show a connected pattern running through Afghanistan (i.e. $IT^{KK\text{-}E}$ and IT^{E}, totally with 121 species). A number of these plant species have been discovered and recorded for the flora of Iran during the last 15 years (Aydani et al. 2006; Joharchi and Akhani 2006; Memariani et al. 2007; Fritsch and Maroofi 2010; Memariani and Arjmandi 2013; Joharchi and Nejati 2015; Memariani et al. 2016c; Arjmandi et al. 2016; Nasseh and Joharchi 2019; Behroozian et al. 2019) and this demonstrates the role of the KK mountains as a refuge for the Middle/Central Asian flora. There are also several species occurring mainly in the KK mountainous areas, and further west in the eastern Alborz and sometimes even into the central and western Alborz (i.e. $IT^{KK\text{-}Alborz}$, 87 species) as well as in KK and slightly eastward to the western and north-central parts of Afghanistan (i.e. $IT^{KK\text{-}Afgh.}$, 83 species). Several species occur mainly from the Caucasian mountains through the Alborz to the KK or occur in the Caucasus/Alborz/Zagros with few disjunct locations in the KK (i.e. $IT^{Cauc.\text{-}Turk.}$, $IT^{Cauc.\text{-}Alborz}$, IT^{Alborz}, and IT^{W}, totally with 63 species). Although KK is mainly a mountainous area, there are several halophytes and some psammophyte elements of the Turanian deserts (i.e. $IT^{Aralo\text{-}Caspian}$, 37 species) in the vast plains and foothills between the mountain systems of the area. These elements sometimes penetrate further south to the central Iranian deserts.

3.5 Endemism

An inventory and appraisal of the whole endemic flora of the KK generated an updated checklist of 356 local or narrow endemics; 178 (50%) of these are endemic to Iran, 59 (16.6%) are endemic to Turkmenistan, and 119 (33.4%) are common between the two countries (Memariani et al. 2016b). The level of endemism in the KK flora is about 14% which is higher than the average in the mountains of the Central Asia (Sennikov 2016). Most of the KK endemic species occur in montane steppe communities from the mid-mountain belt to the subalpine zone, but a considerable number (ca. 20%) of the endemic and sub-endemic species belong to the unique foothill and lowland habitats such as calcareous, serpentine and gypsum ecosystems (Kurbanov 1994; Memariani 2018).

The endemic vascular plants of the KK belong to 112 genera and 36 families. The Dicots with 324 taxa (91%) and 29 families are the most diverse endemics in the area. Only 32 (9%) taxa and 7 families belong to the Monocots. There are no endemic Gymnosperms and Pteridophytes in the area. Asteraceae and Fabaceae are the richest families with 105 (30%) and 95 (27%) endemics, respectively. Like in other areas of the IT region, the genera *Astragalus* (69 species) and *Cousinia* (66 species) show the highest number of endemics in the KK followed by *Allium* (15 species) and *Acantholimon* (14 species). Hemicryptophytes (231 taxa, 65%) are the dominant life-form of the endemics which perhaps reflects that the endemics are well adapted to the cold semi-arid climate of the mountainous island of the KK. The next groups are chamaephytes (61 taxa, 17%), geophytes (36 taxa, 10%), therophytes (18 taxa, 5%) and phanerophytes (10 taxa, 3%).

Considering the five geographical zones of the area, the central part of the KK comprises a higher number (227 taxa) of endemic species, but there are fewer endemics in the southern parts (59 taxa) than in the northwestern parts (65 taxa; Table 3.4). A total of 188 taxa (52.8%) are exclusively distributed in each one of the main geographical zones i.e. northwestern, western, central, eastern or southern parts. The other taxa have a common distribution range in two or more zones.

The species turnover map (beta diversity) reveals that four main areas have the highest magnitude of change in endemic composition among the surrounding areas; they are located in the central, eastern, western and northwestern areas, respectively (Fig. 3.3). The relatively vast area in the central KK with a higher species turnover (beta diversity) reveals the great rate of its compositional dissimilarity in endemics of all geographical zones of the KK.

Table 3.4 The number of endemic species of the KK present in the different geographical zones of the KK

Geographical zone	NW	W	C	E	S
Number of KK endemics	65	116	227	144	59
Proportion of total KK endemics	18.3%	32.6%	63.9%	40.6%	16.6%

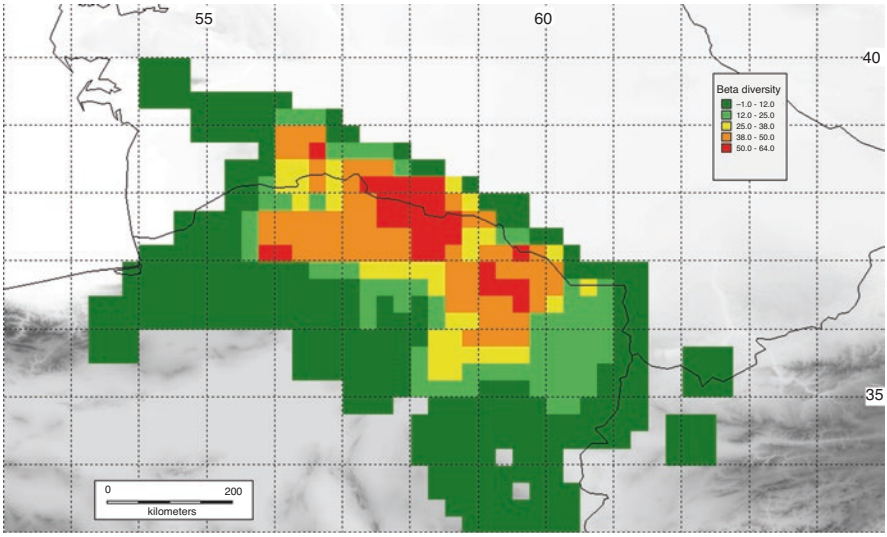

Fig. 3.3 Map of beta diversity (Whittaker's species turnover values) of endemic plants in 15′ grid cell areas of the KK (Memariani et al. 2016b)

3.6 Major Vegetation Types

Despite the uniform and relatively dry climatic conditions throughout the KK, the complicated topography and high habitat heterogeneity as well as a long vegetation history allowed the development of diverse vegetation types in the area. The spatial structure of the vegetation in many areas of the KK is very complex, and the boundaries between mountain belts are not distinct. Moreover, there are very few comprehensive surveys on the classification of the vegetation in the area. However, several vegetation types in natural and semi-natural environments of the area have been distinguished (Memariani et al. 2016a):

3.6.1 Isolated and Relict Hyrcanian Montane Forests and Shrublands

In western parts of the KK (western Aladagh range in Darkesh and Jowzak area), about 80 km away from the easternmost limit of Hyrcanian forests in the Golestan National Park, some enclaves of the Hyrcanian montane forests and scrubs consisting mainly of *Quercus castaneifolia* occur at elevations of 1200–1900 m a.s.l. (Fig. 3.4a). Due to the rocky and steep slopes of the northern hillsides and valleys of the area, *Q. castaneifolia* is often growing as short trees and shrubs. There are also some rather pure forests of *Carpinus orientalis* along the wet northern valleys

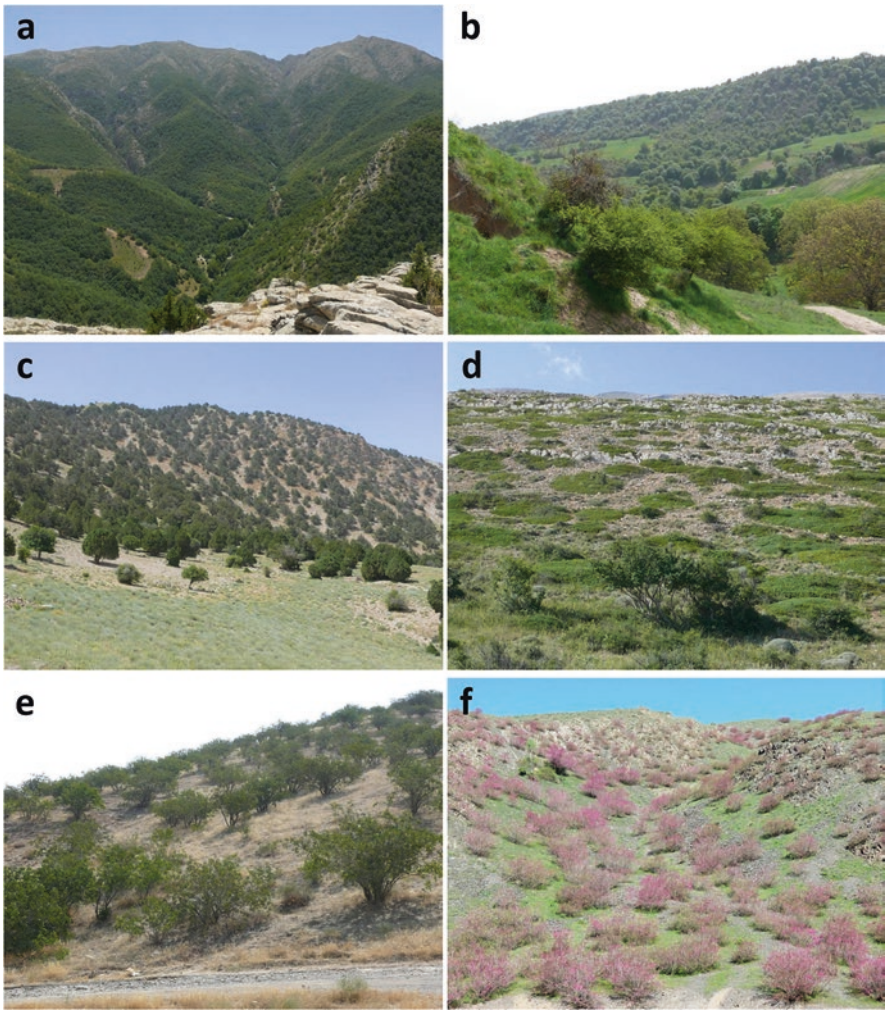

Fig. 3.4 The representative forests, woodlands, and shrublands in the KK mountains. (**a**) Relict Hyrcanian oak forest (*Quercus castaneifolia*) in the western Aladagh mountains; (**b**) Open *Acer monspessulanum-Crataegus* spp. shrubland in the western KK; (**c**) *Juniperus polycarpos* woodland and adjacent *Artemisia kopetdaghensis* mountain steppe in the Ghorkhod Protected Area; (**d**) *Juniperus communis* scrub on northern slopes of Ghorkhod Mt.; (**e**) *Pistacia vera* woodland in the Jangal-e Khajeh Protected Area, the eastern KK; (**f**) *Cercis griffithii* open scrub in the Arghavan valley, Binalood mountains

of the Ghorkhod Protected area. *Acer cappadocicum*, *Mespilus germanica*, *Prunus divaricata*, *Euonymus velutina*, *Pyrus boissieriana*, *Cornus sanguinea* subsp. *australis* and some *Crataegus* species are the main tree and shrub species in this vegetation type.

3.6.2 Juniperus *Woodlands*

Juniperus polycarpos var. *turcomanica* woodlands dominate a vast area in the middle to high mountains of the KK and extend from the northwestern Kopet Dagh to eastern Khorassan in the Bardu and Bezd mountains in Torbat-e Jam. The altitudinal range of these woodlands varies from 850 m a.s.l. in the Raz and Jargalan region up to 2400 m a.s.l. on Ghorkhod Mt. These woodlands have disappeared or have been damaged at many lower, accessible areas by the human. In the NW Kopet Dagh (Turkmenistan), single juniper trees may be found at altitudes of 200–300 m a.s.l. (Fet 1994a). However, well-developed *Juniperus* woodlands can be seen in some protected areas, such as the eastern parts of the Golestan National Park, Salook National Park, Sarani Protected Area, Kopet Dagh Nature Reserve (Turkmenistan), Tandooreh National Park, and the Ors-e Sistan (Hezar-Masjed) Protected Area. Very dense old-growth stands of *Juniperus polycarpos* occur in the Ghorkhod Protected Area (Fig. 3.4c) and the Golestan National Park (Memariani et al. 2016c). Very diverse woody and herbaceous species accompany these woodlands. Open juniper woodlands in the middle and higher belts intermix with *Paliurus spina-christi* and *Acer monspessulanum* scrub, *Artemisia* communities and mountain thorn-cushion steppes.

Juniperus communis and *J. sabina* scrubs form carpet-like vegetation patches on exposed rocks in subalpine areas of the western KK, especially on the northern slopes of the Aladagh, Ghorkhod and on the top of several mountains in the Golestan National Park at altitudes from 1600 to 2600 m a.s.l. (Fig. 3.4d). However, towards the east these occur mostly as individual shrubs or in small patches that do not form actual communities except for the rocky northern slopes of Ghorkhod Mt. On the rocky lower slopes of these mountain areas, *J. communis* may cover the understory of *Carpinus orientalis* scrub.

3.6.3 Pistacia vera *Woodlands*

The isolated xerophilic stands of the wild pistachio (*Pistacia vera*), classified as subtropical semi-savanna, occur between altitudes 800 and 1200 m a.s.l. from the western to eastern Kopet Dagh and also in adjacent areas of the Paropamisus foothills in the Badghys, Pulikhatum and Kushka forest reserves, which cover a total of 75,000 ha (Zlotin 1994; Khanazarov et al. 2009). Well-developed woodlands of *P. vera* (Fig. 3.4e), with a surface area of 17,500 ha, are located in the Jangal-e Khajeh Protected Area adjacent to the Turkmenistan border in the eastern Kopet Dagh (Karimi et al. 2009). The only remaining populations of *P. vera* in the western KK are located in the Qazanqayeh forest reserve (7000 ha), in the east of the Maraveh Tappeh (Golestan province). Very scattered wild pistachio woodlands can be seen in the central Kopet Dagh, in the Kuruhaudan area of Turkmenistan (Kamakhina 1994) and the Polgerd and Daregaz area of Iran. Due to the low

precipitation and high maximum temperature, the understory layer is mainly covered by winter and early-spring ephemeroids, including grasses such as *Poa bulbosa* L. and the sedge *Carex pachystylis* J.Gay (Popov 1994). The wild pistachio woodlands provide valuable genetic resources for *P. vera* which is grown commercially worldwide for its nuts, and Iran is the major pistachio producer in the world.

3.6.4 Open Mesophilic Shrublands

There is a suitable microclimate along the moist valleys of the KK mountains for shrubland vegetation types. These open mesophilic shrublands have different species composition depending on the altitude and slope aspect. *Acer monspessulanum* subsp. *turcumanicum* is the main endemic component of these plant communities in the west to east-central KK, along with *Cotoneaster, Crataegus*, *Lonicera* and *Prunus* species (Fig. 3.4b). The successional scrubs of *Paliurus spina-christi* grow in valleys and along seasonal rivers and streams of the northwest and western KK. In the mesic conditions of the western Aladagh and Ghorkhod ranges, the understory of these open shrublands and scrubs (šibljak communities) is enriched by many KK endemics and also by Hyrcanian and ES species. These communities are accompanied by other shrubby species, such as *Jasminum fruticans*, *Rhamnus pallasii*, *Rubia florida*, and *Colutea porphyrogramma*. Along permanent rivers, especially in the western KK, there are usually narrow strips of mountain riparian communities composed of *Juglans regia* and *Platanus orientalis* (mainly cultivated), *Cornus sanguinea* subsp. *australis*, *Fraxinus angustifolia*, *Lonicera floribunda*, *Prunus divaricata*, and *Rubus sanctus*. The understory layer is mainly covered by mesophilic herbaceous species. In some parts of the Binalood Mountains, mainly in the Arghavan valley, there is a Mediterranean type of open scrub formed by *Cercis griffithii* (Fig. 3.4f).

3.6.5 Montane Steppe Shrublands

Well-developed and very diverse mountain steppes form the main formations in the mid-mountain belt above the semi-desert *Stipa-Artemisia* steppe. These are mainly thorn-cushion communities and grassy mountain steppes, or combinations, with scarce shrubs depending on altitude, humidity, soil type and degree of disturbance. *Astragalus verus* is usually the most dominant species of these habitats. Well-developed *Elymus hispidus* grassland covers higher mountains in some areas, where scattered *Acer* or *Crataegus* shrubs can also be seen (Fig. 3.5d). Montane steppe shrublands are highly enriched by many diverse and endemic plants, such as species from the genera *Astragalus*, *Cousinia*, *Allium*, *Euphorbia*, *Silene* and *Alyssum* which may form some unique plant communities or intermix and make patches

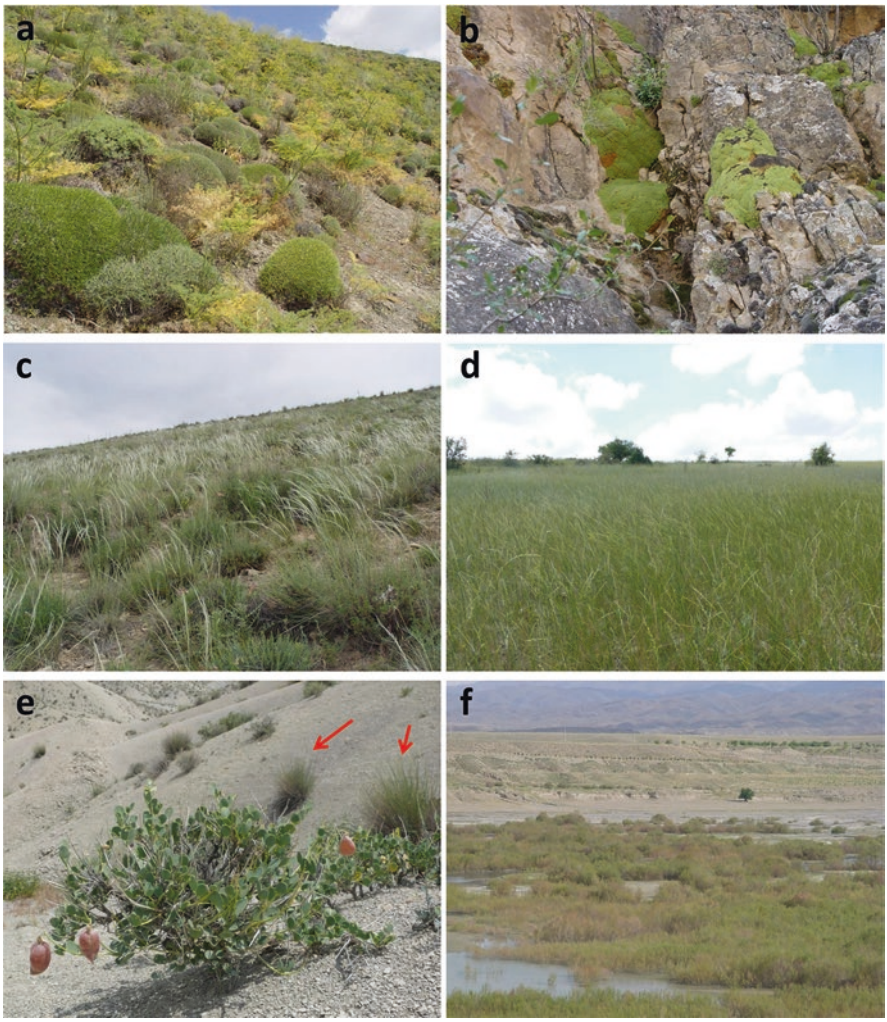

Fig. 3.5 Some representative mountain steppes, foothill and plain vegetation in the KK. (**a**) Thorn-cushion vegetation in subalpine areas near the summit of the Binalood; (**b**) A typical cliff vegetation with dominant *Gypsophila aretoides* in the Aladagh mountains; (**c**) *Stipa-Artemisia* steppe in northern foothills of the Binalood mountains; (**d**) *Elymus hispidus* grassland in the Ghorkhod Protected Area; (**e**) *Colutea gifana* (Critically Endangered) with *Klasea leptoclada* (Endangered) in the background (arrows) on calcareous/marl hills of the western KK in North Khorassan; (**f**) *Tamarix* scrub community along the Abghad river in northern plains of the Binalood range

within other vegetation types in mountainous areas, as in *Juniperus* woodlands and open shrublands.

3.6.6 Subalpine Thorn-Cushions

These mountains are not so high to support high alpine habitats but the subalpine vegetation types are well-developed in high elevations. These habitats are mostly covered by thorn-cushion formations which usually composed of *Onobrychis cornuta*, *Acantholimon*, and *Acanthophyllum* species and tragacanthic *Astragalus*. Grassy steppes, mainly composed of *Festuca valesiaca* Gaudin and *Stipa* species, have developed in protected areas. In some parts, these communities are mixed with tall umbelliferous communities that are dominated by *Ferula, Ferulago* and *Prangos* species (Fig. 3.5a).

3.6.7 Stipa-Artemisia *Steppes (Semi-desert Steppes)*

Stipa-Artemisia communities are among the main vegetation types of the area, occupying lower plains and foothills and forming pure steppe or mixed communities (Fig. 3.5c) depending on elevation, erosion, precipitation and soil salinity. Several *Artemisia* species make shrub steppes, such as *A. inculta* (=*A. sieberi*) in lower plains, or *A. ciniformis* and *A. kopetdaghensis* in foothills and mid-mountains (Fig. 3.4c). These communities include relatively diverse annuals and they form different associations in the area. The mid-mountain *Stipa-Artemisia* communities are intermixed and co-dominated by several grasses of mountain steppes, especially *Festuca valesiaca* and *Stipa* spp. or with dwarf shrubs such as *Ephedra intermedia* and *Hymenocrater* species (Fet 1994a).

3.6.8 Chasmophytic Vegetation

Steep rocky slopes and walls in valleys and canyons provide suitable, inaccessible habitats for the diversification of many chasmophytic species in the area. Although plant associations in these habitats have not been well documented, they are identified by several characteristic species, such as *Dielsiocharis kotschyi, Dionysia tapetodes*, *Graellsia integrifolia*, *Gypsophila aretioides* (Fig. 3.5b), *Parietaria judaica*, *Rosularia subspicata*, and *Scrophularia variegata*. At lower altitudes in the western part of the KK, cliff vegetation is usually associated with C4 grasses (Akhani and Ziegler 2002; Memariani et al. 2016c).

3.6.9 Edaphic Vegetation on Serpentine, Calcareous and Gypsum Soils

Various types of marl, gypsum, serpentine, and calcareous formations dating from the Oligocene to Cretaceous substrates, occur in the KK (Afshar-Harb 1994). The vast foothill areas of the west-central KK in North Khorassan Province are covered by marl hills and calcareous formations with a flora much more differentiated than in adjacent areas (Fig. 3.5e). The ophiolitic rocks have produced serpentine soils in vast areas of the Sabzevar and Kashmar-Torbat ranges. There are also several veins of gypsum hills in these ranges, especially in Robat-e Sefid. The vegetation on such hills is very sparse and poor in species. The carbonate-rich soils, the serpentine and gypsum, the very dry substrate, and the lack of organic material represent stressful conditions for many plant species. Therefore, highly specialized xerophilous species grow on such soils. These habitats are well known for having local edaphic endemics (Rechinger 1989; Eftekhari et al. 2002; Memariani 2018).

3.6.10 Halophytic Vegetation

Vast areas of the main plains between the mountain systems of the KK and also along with salt and brackish springs and seasonal saline streams are covered by saline soils and inhabited by diverse halophytic communities. The main halophytic vegetation types are the riparian *Tamarix* scrub communities along with the seasonal or permanent saline and brackish rivers and streams (Fig. 3.5f), plus *Phragmites australis*, and C4-dominated annual halophytic vegetation in ruderal and saline wastelands, and shrubby halophytic and *Haloxylon ammodendron* communities. Shrubby halophytic communities are formed mostly by *Anabasis aphylla*, *Halocnemum strobilaceum*, and *Salsola arbusculiformis*.

3.6.11 Psammophyte Vegetation

The peripheral plains of the KK have been penetrated by sand-desert elements, mainly on fixed sandy soils or sand-clay alluvial plains. These are mainly communities of *Haloxylon ammodendron*. They form on fixed sands – or are cultivated in some areas, especially around Sabzevar and Sarakhs towards Taybad. Other woody species are rare in these communities except for *Ephedra strobilacea* and *Astragalus bazarganii*, but the community is relatively rich in herbaceous ephemeroid plants, especially in early spring with higher precipitation. These include *Carex physodes*, *Eminium lehmannii*, *Iris longiscapa, Tulipa lehmanniana*, and *Ungernia trisphaera*.

3.6.12 Aquatic, Riverine and Hygrophilous Communities

Several aquatic and hygrophilous vegetation types occur within and around temporary and permanent water resources, such as springs, streams, rivers, waterfalls and small lakes. The plant diversity around Bazangan Lake, the largest permanent lake in the area, has been documented by Gholami et al. (2006). Some of the main species of these communities, formed mainly along freshwater streams, are *Cyperus longus*, *Epilobium hirsutum*, *Eupatorium cannabinum*, *Lythrum salicaria*, *Mentha longifolia*, *Phragmites australis*, *Typha latifolia*, *Veronica anagallis-aquatica*, and *Juncus*, *Carex*, *Salix* and *Populus* species.

3.6.13 Alien and Ruderal Communities

Intensive human activities have affected the natural vegetation of the area during the last century. Many alien, weedy and ruderal species have colonized the disturbed vegetation types in urbanized and grazed areas, roadsides and cultivated lands. *Ailanthus altissima*, a fast-growing exotic tree, has invaded the riparian vegetation of the Tandooreh National Park.

3.7 Conservation

In recent decades, the increase in the human population, urbanization, and industrialization caused extensive degradation in the natural ecosystems and the biodiversity of the KK. Overgrazing and over-exploitation are among the main disturbance factors. Since the last century, the unique *Juniperus* woodlands of the KK have been damaged because of the gathering of firewood and the cutting of timber, except in inaccessible or protected areas. Vast *Pistacia vera* woodlands have been over-exploited for nut and resin production (Zlotin 1994) or through overgrazing (Popov 1994). Habitat loss and continuing aridification of the area threaten its unique plant biodiversity through the extinction of several narrow endemics as well as many mesophilic and regionally rare species inhabiting moist valleys of the western KK. While several areas are currently under protection, the woodland habitats continue to experience heavy logging and over-grazing, and enforcement is not always adequate to promote forest regeneration (Atamuradov et al. 1999). About 1.3 million ha of the KK and surrounding transition zones (ca. 8% of its surface area) are officially protected under different protection schemes. Among the 38 designated protected regions in the area, 4 are National Parks, 20 Protected Areas, 5 Wildlife Refuges, and 6 Natural Monuments in Iran and 3 are Nature Reserves in Turkmenistan (Memariani et al. 2016a). However, most of these areas have been managed only for the last 15 years, and their natural habitats have been moderately degraded and

experienced a disturbance history. Only a few areas have a history of more than 30 years of protection, for example, the Golestan and Tandooreh National Parks, the Ghorkhod and Sarani Protected Areas, and the Miandasht and Khosh Yeilaq wildlife refuges, all in Iran. Many important plant areas, such as the relict *Quercus castaneifolia* montane forests in the western Aladagh, the floristically rich valleys on the northern slopes of the Salook and Binalood mountains, and several fragile ecosystems and vegetation types of the area, particularly the edaphic vegetation on serpentine, calcareous and gypsum soils, are not under legal protection. Plant biodiversity and ecosystems in the area need more effective *in situ* conservation through the establishment of protected areas and taking into account the distribution of vegetation types and centers of plant diversity and hot spots for threatened flora.

Memariani et al. (2016b) prepared the Red-List of the endemic flora of the KK (see some examples in the Fig. 3.6) and revealed that a total of 200 (56%) endemic taxa are globally Threatened including Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) taxa (Table 3.5). Moreover, 32 taxa (9%) that were considered to be Near Threatened (NT) are likely to be qualified for a threatened category in the near future (IUCN 2011). Only 29 widespread and abundant endemic taxa have been evaluated as Least Concern (LC) which means a low risk of extinction. Two endemic species, *Cousinia oreoxerophila* and *Dionysia kossinskyi* are estimated to be extinct (EX) in the KK (Kamakhina 1994). A considerable number of endemic taxa (26.1%) in the KK are categorized as DD because of inadequate information on their taxonomy and/or distribution for Red Listing.

The endemic taxa under extremely high (CR), very high (EN) and high (VU) risk of extinction, and also the centers of endemism are priority targets for conservation actions. There are well-established protected areas in many endemic hotspots of the area partly supporting *in situ* conservation of main populations of several threatened species; for example the Tandooreh National Park, Sarani Protected Area, Dorbadam P.A., Sarigol P.A. (Iran) and the Kopet Dagh Nature Reserve (Turkmenistan) in the central KK; Hezar-Masjed P.A. in the eastern KK; Golestan N.P. and the Ghorkhod P.A. in western KK; and the Syunt-Khasardag N.R. (Turkmenistan) in the northwestern KK. However, several areas with a high endemic richness or endemic distinctiveness are not officially protected such as eastern parts of the Binalood range, the Aladagh range and northern slopes of the Salook Mt. Almost all populations of endemic taxa outside the protected areas are severely subjected to one or more threatening factors, mainly habitat loss through over-grazing, agricultural activities, road constructions, expansion of human settlements and industrial areas. Range loss can lead to the global extinction of many of these endemic plants. Recently, some efforts have been initiated for the conservation of endemic and threatened plant species of the KK (Nadjafi et al. 2006; Kiani et al. 2010, 2013). However, more work is needed for *ex situ* conservation of these prioritized taxa using seed banking, *in vitro* propagation and cultivation in botanical gardens.

Fig. 3.6 Selected Red-Listed plant species endemic to the KK. (**a**) *Allium aladaghense*, an endangered species and endemic to the Aladagh, Salook, and the Ghorkhod Mt. in the western KK (Memariani et al. 2012); (**b**) *Iris ferdowsii*, an endangered and endemic species in the Hezar-Masjed mountain range in the east-central KK (Memariani and Joharchi 2017); (**c**) *Astragalus fuhsii*, a vulnerable species endemic to the western Kopet Dagh and Binalood ranges; (**d**) *Hedysarum monophyllum*, a vulnerable species and endemic to gypsum and marl hills in the west-central KK; (**e**) *Cousinia edmondsonii*, a critically endangered species known only from the summit of Ghorkhod Mt. in the western KK; (**f**) *Psephellus galactochrous*, an endangered and endemic species to calcareous foothills in the west-central KK; (**g**) *Diaphanoptera stenocalycina*, an endangered species endemic to the saline plains the south of Ghorkhod and Aladagh ranges in the western KK; (**h**) *Veronica khorassanica*, a Near Threatened endemic plant widely distributed from the west to the east of the KK mountains

Table 3.5 Red List categories for the KK endemic flora

IUCN Red List Categories	Extinct (EX)	Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Near Threatened (NT)	Least Concern (LC)	Data Deficient (DD)	Not Evaluated (NE)
Number of Species	2	24	72	104	32	29	93	0

References

Afshar-Harb A (1969) A brief history of geological exploration and geology of the Sarakhs area and the Khangiran field. Bull Iran Petrol Inst 37:86–93 [in Persian]

Afshar-Harb A (1979) The stratigraphy, tectonics and petroleum geology of the Kopet Dagh region, northern Iran. Unpublished Ph.D. thesis. Imperial College of Science and Technology, London, 316 pp

Afshar-Harb A (1994) Geology of Kopet Dagh. In: Hushmandzadeh A (ed) Treatise on the geology of Iran, No. 11. Geological Survey of Iran, Tehran, pp 1–275 [in Persian]

Akhani H (1998) Plant biodiversity of Golestan National Park, Iran. Stapfia 53:1–411

Akhani H (2005) The illustrated flora of Golestan National Park, Iran, vol. 1. Tehran University Press, Tehran, 481 pp

Akhani H, Kürschner H (2004) An annotated and updated checklist of the Iranian bryoflora. Cryptogam Bryol 25(4):315–347

Akhani H, Ziegler H (2002) Photosynthetic pathways and habitats of grasses in Golestan National Park (NE Iran), with an emphasis on the C4-grass dominated rock communities. Phytocoenologia 32(3):455–501

Amiri MS, Jabbarzadeh P (2011) Floristic study of Zangelanlo watershed (Khorassan, Iran). Taxon Biosystem 2:1–16 [in Persian with English abstract]

Arjmandi AA, Sharghi HR, Memariani F, Joharchi MR (2016) *Rosa kokanica* (Rosaceae) in Binalood Mountains: a new record for the flora of Iran. Iran J Bot 22:11–15

Assadi M, Maassoumi AA, Khatamsaz M, Mozaffarian V (eds) (1988–2018) Flora of Iran, vols. 1–149. Research Institute of Forests and Rangelands Publications, Tehran [in Persian]

Atamuradov HI, Fet GN, Fet V, Valdez R, Feldman W (1999) Biodiversity, genetic diversity, and protected areas in Turkmenistan. J Sustain Forest 9(1):73–88

Atashgahi Z, Ejtehadi H, Mesdaghi M, Ghassemzadeh F (2018) Plant diversity of the Heydari Wildlife Refuge in northeastern Iran, with a checklist of vascular plants. Phytotaxa 340(2):101–127

Aydani M, Joharchi MR, Ghahremaninejad F (2006) A new record, *Galatella litvinovii* (Asteraceae) from Iran, N Khorassan province. Iran J Bot 12:203–204

Behroozian M, Ejtehadi H, Memariani F, Joharchi MR, Mesdaghi M (2019) *Stipa richteriana* (Poaceae) and *Galium songaricum* (Rubiaceae): two new additions of the central Asian species to the flora of Iran. Nova Biologica Reperta 6(3):326–333

Berberian M, King GCP (1981) Toward a palaeogeography and tectonic evolution of Iran. Can J Earth Sci 18:210–265

Djamali M, Akhani H, Khoshravesh R, Andrieu-Ponel V, Ponel P, Brewer S (2011) Application of the Global Bioclimatic Classification to Iran: implications for understanding the modern vegetation and biogeography. Ecologia Mediterranea 37(1):91–114

Djamali M, Baumel A, Brewer S, Jackson ST, Kadereit JW, López-Vinyallonga S, Mehregan I, Shabanian E, Simakova A (2012) Ecological implications of *Cousinia* Cass. (Asteraceae) persistence through the last two glacial-interglacial cycles in the continental Middle East for the Irano-Turanian flora. Rev Palaeobot Palyno 172:10–20

Eftekhari T, Assadi M, Mahmoudi S, Dadkhahipour K (2002) Flora of gypsy area in Robat-Sefid (Khorassan province). Pajouhesh & Sazandegi 56–57:81–94 [in Persian]

Fet GN (1994a) Vegetation of southwest Kopetdagh. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 149–172

Fet V (1994b) Biogeographic position of Khorassan-Kopetdagh. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 197–204

Fritsch RM, Maroofi H (2010) New species and new records of *Allium* L. (Alliaceae) from Iran. Phyton (Horn, Austria) 50:1–26

Ghahreman A, Heydari J, Attar F, Hamzeh'ee B (2006) A floristic study of the southwestern slopes of Binaloud elevations (Iran: Khorassan Province). J Sci (Univ Tehran) 32(1):1–12

Ghahremaninejad F, Joharchi MR, Vitek E (2005) New plant records for Khorassan province, Iran [I]. Annalen des Naturhistorischen Museums in Wien 106B:255–293

Ghahremaninejad F, Joharchi MR, Vitek E (2010) New plant records for Khorassan province, Iran, III. Annalen des Naturhistorischen Museums in Wien 111B:135–148

Ghahremaninejad F, Joharchi MR, Vitek E (2012) New plant records for Khorassan province, Iran, V, with complementary notes to its flora. Annalen des Naturhistorischen Museums in Wien 114B:59–94

Gholami A, Ejtehadi H, Ghassemzadeh F, Ghorashi-al-Hosseini J (2006) Study of plant biodiversity around protected area of the Bazangan Lake. Iran J Biol 19(4):398–407 [in Persian]

Haghipour A, Aghanabati A (1989) Geological map of Iran, 1:2,500,000 scale, 2nd edn. NIOC, Tehran

Hubber H (Compiler) (1976) Geological map of Iran, 1:1,000,000 scale (Sheet No. 3). Geological map of north-east Iran. Exploration and production, NIOC, Tehran

IUCN (2011) Guidelines for using the IUCN red list categories and criteria. Version 9.0. Prepared by the Standards and Petitions Subcommittee. Available from: http://www.iucnredlist.org/%20documents/RedListGuidelines.pdf . Accessed 3 Feb 2016

Joharchi MR, Akhani H (2006) Notes on the flora of Iran 6: eight new plant records from Iran collected from Khorassan and Golestan provinces (NE Iran). Rostaniha 7(suppl. 2):131–141

Joharchi MR, Nejati M (2015) A new record of *Primula* L. (Primulaceae) from Iran. Iran J Bot 21:10–12

Joharchi MR, Ghahremaninejad F, Vitek E (2007) New plant records for Khorassan province, Iran [II]. Annalen des Naturhistorischen Museums in Wien 108B:288–301

Joharchi MR, Ghahremaninejad F, Vitek E (2011) New plant records for Khorassan province, Iran, IV; with complementary notes to its flora. Annalen des Naturhistorischen Museums in Wien 112B:329–367

Kalantari A (1969) Foraminifera from the Middle Jurassic-Cretaceous successions of Kopet Dagh region (NE Iran). Ph.D. thesis, London University. Exploration and Production, NIOC, Geological Laboratory Publication 3, Tehran, 298 pp

Kamakhina GL (1994) Kopetdagh-Khorassan flora: regional features of central Kopetdagh. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 129–148

Kamelin RV (1970) Specific phyto-geographical features in the flora of the soviet part of the Kopet-Dag Range. Botanicheskii Zhurnal 55(10):1451–1462 [in Russian]

Kamelin RV (1973) Florogenetic analysis of natural flora of Central Asia. Nauka, Leningrad, 356 pp [in Russian]

Karimi HR, Zamani Z, Ebadi A, Fatahi MR (2009) Morphological diversity of *Pistacia* species in Iran. Genet Resour Crop Ev 56:561–571

Khanazarov AA, Chernova GM, Rakhmonov AM, Nikolyi LV, Ablaeva E, Zaurov DE, Molnar TJ, Eisenman SW, Funk CR (2009) Genetic resources of *Pistacia vera* L. in Central Asia. Genet Resour Crop Ev 56:429–443

Kiani M, Zarghami H, Tehranifar A, Memariani F (2010) Conservation of *Colutea gifana*, a rare and potential ornamental species, using *in vitro* method. J Cell Mol Res 2(2):81–85

Kiani M, Zarghami H, Memariani F, Tehranifar A (2013) *In vitro* propagation and conservation of *Diaphanoptera khorasanica* (Caryophyllaceae), a threatened endemic and potential ornamental species in northeast of Iran. J Cell Mol Res 4(2):89–96

Kurbanov D (1994) Flora of Kopetdagh. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 105–128

Mahboubi A, Mousavi-Harami R, Mansouri-Daneshvar P, Nadjafi M, Brenner R (2006) Upper Maastrichtian depositional environments and sea-level history of the Kopet-Dagh Intracontinental Basin, Kalat Formation, NE Iran. Facies 52:237–248

Martins L, Hellwig FH (2005) Systematic position of the genera *Serratula* and *Klasea* within Centaureinae (Cardueae, Asteraceae) inferred from ETS and ITS sequence data and new combinations in *Klasea*. Taxon 54(3):632–638

Memariani F (2018) Khorassan- Kopet Dagh Floristic Province (NE Iran, S Turkmenistan): an edaphic endemism hotspot in Irano-Turanian Region. In: Kurt L, Palacio S (eds) GYPWORLD: a Global initiative to understand gypsum ecosystem ecology, Abstract Book: 1st Gypsum Ecosystem Research Conference: Gypsum Ecosystems as Biodiversity Hotspots. 3rd–9th June, Ankara, Turkey

Memariani F, Arjmandi AA (2013) *Festuca karatavica* (Poaceae), a new grass record for the flora of Iran. Iran J Bot 19:57–61

Memariani F, Joharchi MR (2017) *Iris ferdowsii* (Iridaceae), a new species of section *Regelia* from northeast of Iran. Phytotaxa 291(3):192–200

Memariani F, Joharchi MR, Khassanov FO (2007) *Allium* L. subgen. *Rhizirideum* sensu lato in Iran, two new records and a synopsis of taxonomy and phytogeography. Iran J Bot 13:12–20

Memariani F, Joharchi MR, Ejtehadi H, Emadzade K (2009) A contribution to the flora and vegetation of Binalood mountain range, NE Iran: floristic and chorological studies in Fereizi region. Ferdowsi Univ Int J Biol Sci 1:1–17

Memariani F, Joharchi MR, Arjmandi AA (2012) *Allium aladaghense* (Amaryllidaceae, Allieae), a new species of section *Asteroprason* from northeast of Iran. Phytotaxa 56(1):28–34

Memariani F, Zarrinpour V, Akhani H (2016a) A review of plant diversity, vegetation and phytogeography of the Khorassan-Kopet Dagh floristic province in the Irano-Turanian region (northeastern Iran-southern Turkmenistan). Phytotaxa 249(1):8–30

Memariani F, Akhani H, Joharchi MR (2016b) Endemic plants of the Khorassan-Kopet Dagh floristic province in the Irano-Turanian region: diversity, distribution patterns and conservation status. Phytotaxa 249(1):31–117

Memariani F, Joharchi MR, Akhani H (2016c) Plant diversity of Ghorkhod Protected Area, NE Iran. Phytotaxa 249:118–158

Meusel H, Jäger E, Weinert E (1964) Vergleichende Chorologie der zentraleuropäischen Flora, vol. 1. Gustav Fischer Verlag, Jena, 583+250 pp

Meusel H, Jäger E, Rauschert S, Weinert E (1978) Vergleichende Chorologie der zentraleuropäischen Flora, vol. 2. Gustav Fischer Verlag, Jena, 418+171 pp

Meusel H, Jäger E, Bräutigam S, Knapp HD, Rauschert S, Weinert E (1992) Vergleichende Chorologie der zentraleuropäischen Flora, vol. 3. Gustav Fischer Verlag, Jena, 688 pp

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C (2011) Global biodiversity conservation: the critical role of hotspots. In: Zachos FE, Habel JC (eds) Biodiversity hotspots: distribution and protection of conservation priority areas. Springer, Heidelberg, pp 3–22

Nadjafi F, Koocheki A, Rezvani Moghaddam P, Rastgoo M (2006) Evaluation of seed germination characteristics in *Nepeta binaloudensis*, a highly endangered medicinal plant of Iran. J Iran Field Crop Res 4(2):1–8

Nasseh Y, Joharchi MR (2019) A new record of *Lepidium* (Brassicaceae) for the flora of Iran. Nova Biologica Reperta 6(3):347–351

Nikitin V, Geldikhanov A (1988) Manual of plants of Turkmenistan. Nauka, Leningrad, 680 pp [in Russian]

Popov KP (1994) Trees, shrubs and semishrubs in mountains of Turkmenistan. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 173–186

Proskuriakova GM (1971) Some general features of the Bolshoi Balkhan flora. Annalen des Naturhistorischen Museums in Wien 75:203–208

Rechinger K. (ed) (1963–2015) *Flora Iranica*, vols. 1–181. Akademische Druck- u. Verlagsanstalt, Graz; vol. 175. Akademische Verlagsgesellschaft, Salzburg; vols. 176–181. Verlag des Naturhistorischen Museums, Wien

Rechinger KH (1989) Fifty years of botanical research in the Flora Iranica Area (1937–1987). In: Tan K (ed) Plant taxonomy, phytogeography and related subjects, The Davis & Hedge Festschrift. The Botanical Society of Edinburgh, Edinburgh, pp 301–349

Rustamov EA (2012) Turkmenistan: Landscape–Geographical Features, Biodiversity, and Ecosystems. In: Zonn IS, Kostianoy AG (eds) The Turkmen Lake Altyn Asyr and Water Resources in Turkmenistan. Handbook of Environmental Chemistry. Springer, pp. 9–22. https://doi.org/10.1007/698_2012_179

Saberi A, Ghahremaninejad F, Sahebi SJ, Joharchi MR (2010) A floristic study of Chahchaheh Pistacia forest, NE Iran. Taxon Biosystem 2:61–92 [in Persian]

Sennikov AN (2016) The plant world of the Khorassan-Kopet Dagh Floristic Province: a tribute to Eskandar Firouz. Phytotaxa 249:5–7

Takhtajan A (1986) Floristic regions of the world. Translated from Russian. University of California Press, California, 544 pp

Zlotin RI (1994) Ecosystem structure of subtropical arid pistachio woodlands in southern Turkmenistan. In: Fet V, Atamuradov KI (eds) Biogeography and ecology of Turkmenistan. Kluwer Academic Publisher, Dordrecht, pp 187–196